More free publications from Archimer

Updated developments in ultraviolet equipment for shellfish depuration

Évolution réactualisée des matériels UV pour la purification des coquillages

SYDNEY ELLNER
RFD2, Bedford, New York 10506, USA

Abstract

A brief discussion of the physics involved in the destruction of microorganisms by exposure to 2537Å of UV energy:

- *UV dose* required for destruction of various microorganisms in a dynamic UV reactor (Bio Assay).
- *History of UV* design for shellfish depuration :
  Kelly Purdy Overhead design, Closed channel reactors, Open channel horizontal reactors, Open channel vertical reactors.
- *Factors which effect UV* performance:
  Chemical make up of water-coefficient of absorption,
  Physical make up of water-turbidity and Color impact,
  Overall UV transmission limits for effective disinfection.
- *Discussion of the U.S. Public Health Service:* effects of color, turbidity, and bacterial densities on UV performance.
- *Impact of temperature* on UV lamp performance.
- *Impact of coating* on Quartz Jackets.
- *Methods to recognize coatings* and loss of UV transmittance in various design configurations.
- *Depuration UV system:* UV lamp to flow ratios, temperature control, intensity monitoring, lamp life monitoring, cleaning techniques, preferred flow patterns, economics.

Résumé

Une brève discussion de la physique impliquée dans la destruction des micro-organismes par exposition à 2537Å d'énergie UV :

- *Dose d'UV* nécessaire à la destruction de divers micro-organismes dans un réacteur dynamique à U (Bio-essai).
- *Historique des matériels à UV* pour la purification des coquillages :
  Modèle Kelly Purdy Overhead, réacteurs à circuit fermé, réacteurs horizontaux à circuit ouvert, réacteurs verticaux à circuit ouvert.
- *Facteurs influençant la performance des UV :*
  Composition chimique de l'eau - coefficient d'absorption
  Composition physique de l'eau - turbidité et impact de la couleur
  Limite globale de transmission des UV pour une désinfection efficace
- *Discussion sur les services de santé publique aux USA* : effet de la couleur, de la turbidité et des densités bactériennes sur la performance des UV.

– *Impact de la température* sur la performance des lampes à UV.
– *Impact du revêtement* sur les gaines de quartz.
Méthodes pour reconnaître les revêtements et la perte de facteur de transmission UV dans différentes configurations de matériel.
– *Système de purification aux UV* : lampe à UV par rapport aux débits, régulation de température, contrôle de l'intensité, contrôle de la durée de vie de la lampe, techniques de nettoyage, schémas d'écoulement préférentiels, économie.

Ultraviolet treatment of water has been relied upon in the depuration of shellfish for many years. The requirement to disinfect the process sea water to drinking water quality without effecting the metabolism of the shellfish can only be obtained with a process which treats the organisms and not the water. UV at 254 nm is the only practical method to obtain this objective.

Ultraviolet is part of the invisible spectrum having a wavelength between 100 and 400 nanometers. The peak germicidal activity occurs at 254 nm as shown in figure 1. The resonance line of low pressure mercury vapor lamps peaks at 254 nm and it is for this reason that this type of lamp is used exclusively for UV disinfection applications.

Germicidal ultraviolet destroys microorganisms and virus through disruption of the DNA of the exposed cell.

The unit of measurement for ultraviolet disinfection is *microwatt seconds per square centimetre*. Also known as *dosage*, this unit is a function of the UV intensity times the contact time. Various organisms require different UV dosage for inactivation as shown on table I. Coliforms are inactivated by dose levels around 6,600 $\mu w \cdot s/cm^2$.

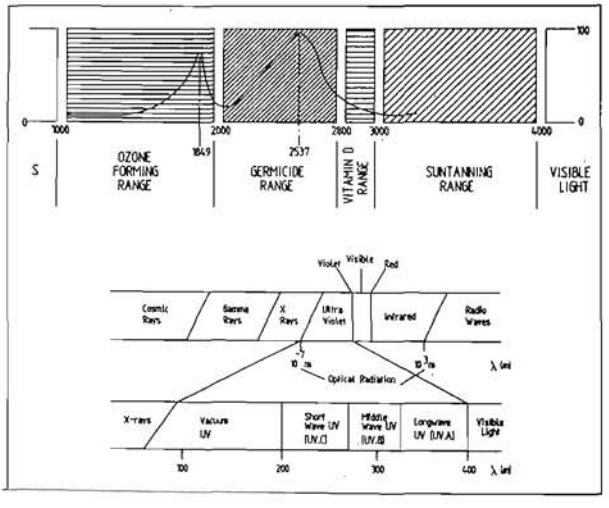

Figure 1: UV spectrum

Table I: UV dose data

Typical organisms	Microwatt.seconds/cm²
Shigella (Various, Inc. Dysentry)	3,400 - 7,000 µws/cm²
E. coli	6,600 µws/cm²
Salmonella (Various, Inc. Enteric & Typhoid Fever)	6,000 - 15,200 µws/cm²
Hepatitis virus	8,000 µws/cm²
Influenza	6,600 µws/cm²
Corynebacterium diphtheriae	6,500 µws/cm²
Legionella (Various)	2,900 - 5,500 µws/cm²
Leptospira interrogans (Infectious Jaundice)	6,000 µws/cm²

Ultraviolet accomplishes disinfection without altering the physical or chemical properties of the water treated. For this reason, it was considered impossible to measure the delivered dosage after water had passed through a UV reactor. In the 1960's Dr Paul Ellner developed a method for measuring the delivered dosage of a UV reactor utilising the principal of bioassay.

This method consists of the following steps:

1. Select a test organism with a high resistance to UV.
2. Determine the dose response curve (% kill for various dose levels) of the selected organism.
3. Introduce a concentration of the test organism to the UV reactor at various flow rate conditions.
4. Sample the concentration of the test organism prior to UV treatment and after the UV treatment.
5. Determine the delivered UV dosage under the test conditions by comparing the % survivors to the dose response curve.

The *B. subtilus* spore was selected as the test organism due to its known high level of resistance to ultraviolet. A static apparatus consisting of a UV lamp, support stand, collimating tube and magnetic mixer (figure 2) is used to determine the dose response of the test organism.

The UV lamp is placed at a specific distance from the surface of the mixer, and the intensity is measured with a standard UV intensity meter. *For this example 1000 µw/cm².*

A pure strain of the test organism is placed in a petri dish on top of the mixer. A sample of the concentration is taken and this is the control count. The UV is turned on, the mixer is turned on, and the test organism is exposed to the *1000 µw/cm²* for 1 second. This is a UV dose of 1000 µw.s/cm².

The exposed sample in incubated and the % survivors is determined by comparing the spore concentration in the sample to the concentration in the control.

This experiment is repeated at various time intervals i.e. 5, 10 15, 20 25 and 30 seconds. The data is then plotted on a dose response curve (figure 3).

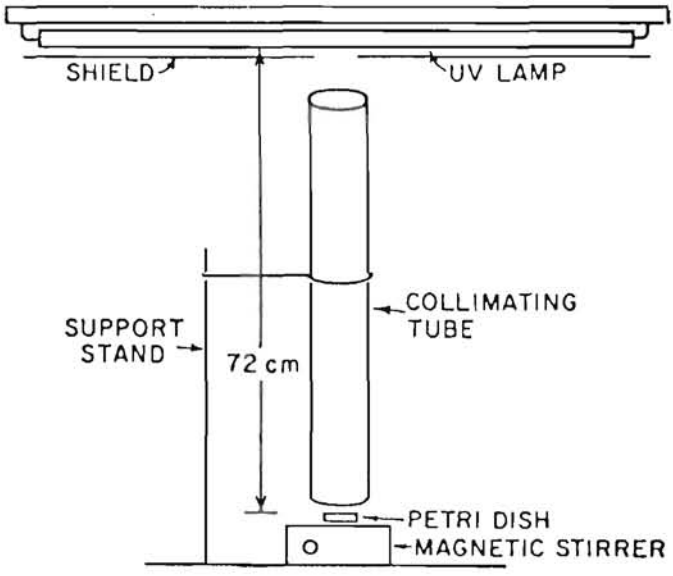

Figure 2: Collimated beam for UV dose determination

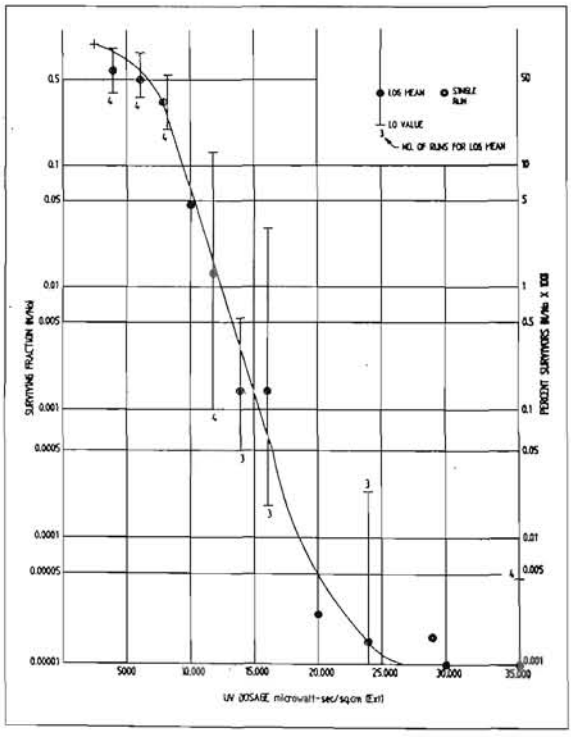

Figure 3: Dose response curve *B. Subtilus* spore

Delivered UV dosage in a specific reactor design is determined as follows: a volume of water is inoculated with a concentration of the same test organism used for determining the dose response curve. This water is then pumped through the reactor and samples are taken before and after the UV treatment. A comparison of the influent concentration and the treated samples is expressed as a % survivor. If the % survivors is 1, we see from the dose response curve that the delivered UV dosage under the specific test conditions is 12,500 $\mu w.s/cm^2$. This dose measuring technique has enabled designers of UV equipment to optimise hydraulic configuration of reactors, determine effect of UV absorption, determine impact of changes in flow rate, and evaluate any other design parameter.

This history of the UV design in the depuration application is most interesting. The early UV design was a device known as the "Kelly Purdy" unit. This consisted of a shallow, corrugated trough with a battery of UV lamps installed above the water line so that the light would shine down into the flowing water. Reflectors were used to improve efficiency. While the bacterial reduction by this system was initially acceptable, there were disadvantages. Efficiency was limited and there was unequal energy distribution. The top of the water flow (closest to the UV lamps) received the highest UV intensity, and the bottom of the trough (furthest from the UV lamps) received the lowest UV intensity. If the lamps were placed close to the flowing water, splashing would occur resulting in UV absorbing coatings on the lamps.

The next stage in the development of UV for depuration was the closed chamber UV reactor (figure 4). This design consists of a chamber in which the UV lamps are installed inside quartz jackets within a cylindrical tube. The water is pumped through the reactor at a specific flow rate based upon the number and length of the UV lamps, and the contact time within the chamber.

This is an efficient configuration due to the immersion of the lamps within flowing water and the cooling effect of the flow on the UV lamps. A UV lamp inside a quartz jacket immersed in water at 55F will have an ambient temperature within the quartz jacket very close to the ideal of 105 degrees F.

The problems with the closed chamber design are as follows:

1. The material of construction must withstand salt water.

Most UV units are constructed of stainless steel. Stainless steel is not suitable for salt water applications.

Plastics are suitable for salt water application, but will breakdown after prolonged exposure to UV light.

2. The quartz lamp jackets are not readily visible. UV absorbing coatings are not easily recognised.

3. The quartz jackets are not easily removed for clearing.

4. The closed chamber creates head losses which may be unacceptable in specific recirculating systems.

The most recent improvement in UV design is the open channel reactor.

The open channel design is available in two configurations, open channel horizontal and open channel vertical.

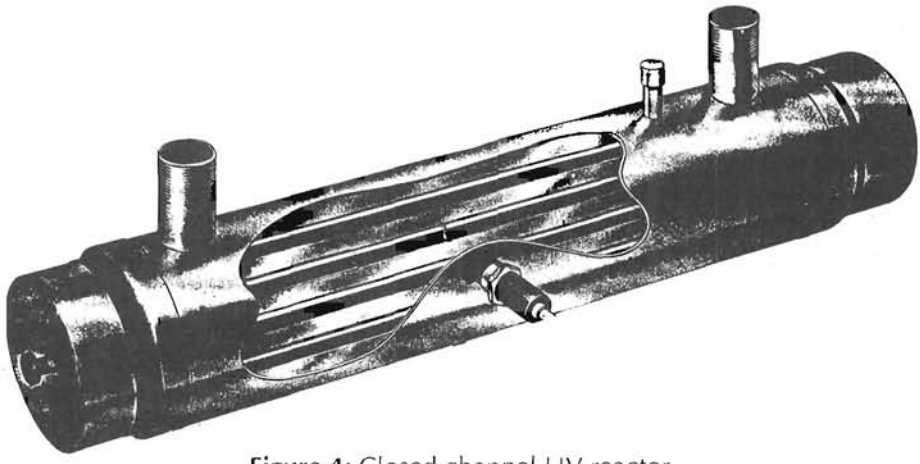

Figure 4: Closed channel UV reactor

The open channel horizontal consists of a rack of UV lamps within quartz jackets which sits within a frame inside of the water flow (figure 5). This system allows for easy visual inspection of the coating on the quartz jackets. Due to the rack design, the entire fixture is easily removable for cleaning of the quartz jackets. This design lends itself to easy retrofit of existing depuration installations since no piping changes are required.

This disadvantages of the open channel horizontal are:

1. The unit has *underwater* electrical connections.
2. The water seal around the quartz jacket must be broken every time the UV lamps are changed.

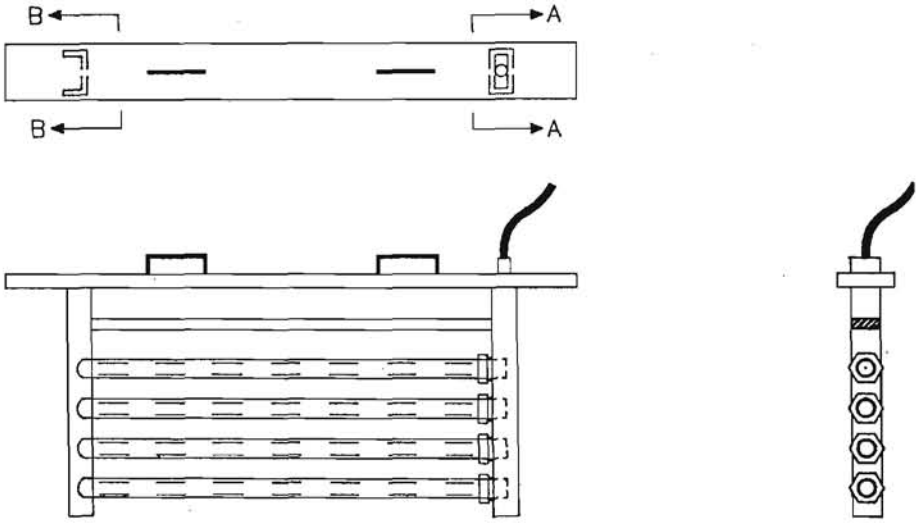

Figure 5: Open channel horizontal reactor. Courtesy ideal horizon-Ultratech

A lamp manufacturer Light Sources, of Milford, Connecticut developed and patented a new UV lamp design. This new lamp was unique in that all the electrical connections were are one end of the lamp (figure 6). The advent of the single ended UV lamp allowed for the design of the Open channel Vertical UV unit.

The open channel vertical UV design consists of a number of single ended UV lamps housed within test tube quartz jackets (figure 7). The quartz jackets are placed vertically in the water flow thus keeping the electrical connections out of the water. This design allows for easy visual inspection of the coating of the quartz jackets. The vertical module is easily removed from the channel for quick cleaning of the quartz jackets. This design lends itself to easy retrofit of existing depuration installations since no piping changes are required.

Unlike the horizontal open channel design, the vertical open channel has no underwater electrical connections, and the UV lamps can be changed without the need to remove the module from the water, or break any water seals. Various regulatory agencies have established specifications for depuration facilities:

Source sea water - Median coli = to or less than 700 total coliform/100 Ml
Salinity - within 20% of harvest area value at the time of harvest
Process water - No detectable coliforms
pH between 7.0 - 8.4
Dissolved Oxygen - minimum 5.0 mg/litter
Temperature - 40F (4.4C) to 68F (20C) soft clams 50F (10C) to 68F (20C) hard clams
Flow-one gallon/minute per U.S. bushel
Process Tanks - 5 cubic feet/bushel for soft clams, 8 cubic feet/bushel for hard clams.

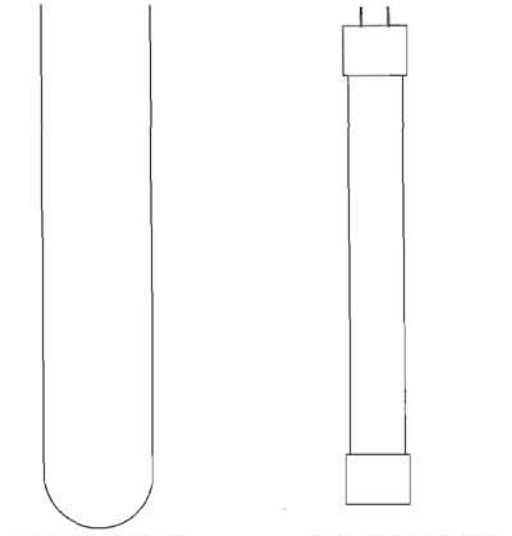

Figure 6: Courtesy of ideal horizons-Ultratech

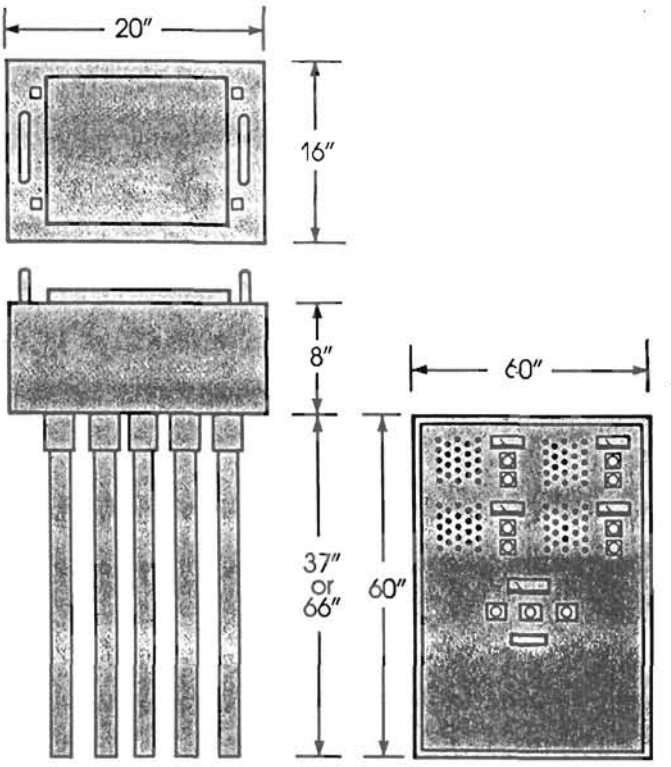

Figure 7: Open channel vertical UV reactor. Courtesy ideal horizon-Ultratech

UV Requirements:

Flow control device

Meter and chart recorder to monitor UV intensity

provisions for cleaning quartz jackets and interior of disinfection chamber

Lamp replacement at 60% of original output 7,500 hours of operation.

Unfortunately, the guidelines do not consider the most significant UV requirement, minimum acceptable dosage. While it is not practical for each facility to conduct their own UV bioassay dose determination, it is possible to compare manufacturers ratings based upon prior delivered dose studies.

The following "rules of thumb" can be helpful in evaluating proposed UV designs :

1. The flow rate should not exceed .3GPM/inch of UV lamp.

There are two standard size UV lamps. 30" arc length, and 58" arc length.

At a flow rate maximum of .3GPM/inch of lamp, the 30" lamp has a flow treatment capability of 9 GPM. The 58" lamp has a treatment capability of 17.4 GPM.

If a depuration plant has a 200 GPM treatment requirement, it would require a UV design with 23 lamps 30" arc or 15 lamps with the 58" arc.

2. The contact time within the reactor must be a minimum of 10 seconds.

In order to have a contact time of 10 seconds, the volume of the UV reactor must be equal to 16.6% of the flow rate. For example a 200 GPM flow rate would require that the reactor have a volume of 33 gallons.

3. The water contact components must withstand salt water and UV energy.

4. Coating on the quartz jackets must be easily recognisable.

5. Coating on the quartz jackets must be easily removed.

6. A UV intensity meter, specific to 254 nm should provide a visual meter reading and a continuous chart recorder record.

The intensity meter must read the UV intensity through the water being treated.

The intensity meter will respond to coatings which form on the quartz jacket, loss in the output of the UV lamp, and changes in the transmission of the water.

7. An elapsed time indicator must be provided to indicate the number of hours the UV lamps have operated.

The elapsed time indicator should operate only when the UV lamps are on, and should be reset each time the lamps are changed.

With the advent of the single ended UV lamp, the Open channel vertical UV reactor offers a new opportunity in the design of shellfish depuration facilities.